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Description

This invention relates to systems for and methods of controlling the temperature of a reactor.

Various methods and systems are known for controlling chemical reactors.

US Patent No. 3 080 219 to Harvey Jr. discloses a control system for a polymerization reactor. This system is applicable to stirred tank reactors where temperatures are uniform throughout the reactor due to mixing.

US Patent No. 4 132 530 to Schwimmer discloses a temperature control system for an exothermic or endothermic reaction. Schwimmer provides a plurality of temperature sensors distributed along the reactor axis for measuring maximum reactor temperatures used in a control scheme.

Other relevant publications are US Patents Nos. 3 373 218 to Schuman, 4 132 529 to Schwimmer, 4 187 542 to Ball et al and 4 257 105 to Stewart et al. All these documents disclose various control techniques for chemical reactors.

In an ethylene oxide manufacturing process, ethylene and oxygen or air are mixed and fed to an isothermal multitubular reactor. Ethylene is oxidized into ethylene oxide in the presence of a catalyst and carbon dioxide and water are produced as by-products. Reactor temperature control objectives are:

operation at the most economical temperature;
operation within a safe zone;
maximum conversion to ethylene oxide while minimizing by-products;
reduced consumption of coolant;
avoidance or elimination of unsafe operation; and
reduced operator attention.

Reactor temperature control is of key significance because of the following factors:

1. The most economical temperature for oxidation is one at which occurs the highest conversion to ethylene oxide rather than to by-products.

2. Catalyst selectivity increases as the reaction temperature is lowered while ethylene conversion increases with increasing reactor temperature. Thus, temperature requirements for high selectivity and high conversion are opposed. This results in a narrow temperature range for reactor operation.

3. Increase in reaction temperature produces two effects: (1) the overall rate of ethlyene oxidation increases, and (2) catalyst selectivity to ethyleneoxide decreases such that relatively more ethylene is converted into carbon dioxide and water. Moreover, heat generation increases due to the fact that more ethylene is oxidized and overall reaction becomes less selective. Consequently, increase in temperature may result in:

a reactor runaway condition;
catalyst poisoning;
increased coolant demand;
an unsafe operating situation; and/or
increased operator attention.

Thus, neither a temperature rise nor a temperature drop is desirable.

In a state of the art system, reactor temperature control is based on manipulating coolant flow rate. A set point of the system is directly based upon average reactor temperature. Such a control scheme results in almost all of the deficiences described above.

US Patent No. US—A—4 257 105 discloses a cracking furnace control system in which a cracking feed is mixed with a diluent fluid such as steam in the cracking furnace. The feedflow and temperature are measured, as are the effluent temperature and composition. A control signal derived from these measurements is used to control flow of the diluent or coolant fluid. This control is effected to maintain either a desired residence time for the feed stream in the cracking furnace or a desired outlet velocity for the effluent.

According to a first aspect of the present invention there is provided a system for controlling the temperature of a reactor for containing a reaction from at least one reactant to at least one product, the reactor having a feed line for the reactant and an effluent line for the product, the system being characterised by:

a feed flow transmitter connected to the feed line for measuring the flow of reactant to the reactor;

an effluent flow transmitter connected to the effluent line for measuring the flow of product from the reactor;

a feed temperature sensor connected to the feed line for sensing the reactant temperature;

an effluent temperature sensor connected to the effluent line for measuring the product temperature;

reactor temperature sensing means connected to the reactor for mesuring a temperature of the reactor;

concentration sensing means connected to the effluent line for measuring the concentration of the at least one product in the effluent line;

a coolant flow line to the reactor for supplying coolant to the reactor at a coolant flow rate;

coolant flow rate control means in the coolant line; and

circuit means that is

(i) connected to the feed and effluent flow transmitters, to the feed and effluent temperature sensors

and to the reactor temperature and concentration sensing means for generating a coolant flow signal,

(ii) connected to the coolant flow control means for controlling the flow of coolant to the reactor according to the coolant flow signal,

(iii) arranged to receive quantities proportional to the heat of reaction for at least one reaction in the reactor, specific heats of the reactant and product, and the heat of vaporization of the coolant, and

(iv) operable to subtract a quantity proportional to an amount of heat consumed in supplying reactant to the reactor from a quantity proportional to an amount of heat generated and lost in the reactor and effluent line and to divide the resulting quantity by the specific heat of the coolant to generate the coolant flow signal.

According to a second aspect of the present invention there is provided a method of controlling the temperature of a reactor for containing an exothermic reaction of at least one reactant to at least one product, by controlling a flow of coolant to the reactor, the method being characterised by:

measuring the feed and an effluent flow rate to and from the reactor of reactant and product;
measuring a feed and effluent temperature;
measuring a reactor temperature;
measuring a concentration of the at least one product in the effluent; and
calculating the coolant flow rate using the formula

$$Q=\frac{1}{\lambda}[F_2\{y_1\Delta H_1+y_2\Delta H_2+C_{P1}(T_R-T_O)\}-F_1C_{PI}(T_R-T_I)]$$

where:

Q=coolant flow rate signal
λ=coolant heat of vaporization
F_2=effluent flow rate
y_1=a first product concentration
ΔH_1=heat of reaction of reactant to first product
y_2=a second product concentration
ΔH_2=heat of reaction of reactant to second product
C_{P1}=specific heat of effluent
T_R=reactor temperature
T_O=effluent temperature
F_1=feed flow rate
C_{PI}=specific heat of feed
T_I=feed temperature.

A preferred embodiment of the present invention described in detail hereinbelow provides a control system and method which permits operation of an olefin oxidation reactor at the most economical and safe temperature range, with regard to a maximum conversion of the olefin to the desired olefin oxide and a minimization of by-products. The preferred control system and method are particularly applicable to ethylene oxidation reactors, but are also applicable to other exothermic and endothermic reactors.

According to the preferred embodiment of the invention, a system is provided which controls the rate of coolant flow in the chemical reactor according to an algorithm which incorporates various parameters including reactor feed and effluent flow rate, specific heat of reactants and products, reactor and effluent temperatures, coolant heat of evaporation, reactant and product concentration and heat of reactions for various reactors taking place in the reactor. In addition, in the preferred embodiment, temperatures are taken at varied locations along the reactor length, for obtaining a maximum and a minimum value for temperatures within the reactor for establishing a desired reactor temperature range. The preferred temperature control system is simple in design, rugged in construction and economical to manufacture.

The invention will now be further described, by way of illustrative and non-limiting example, with reference to the accompanying drawing, the sole figure of which is a schematic representation of a preferred reactor temperature control system embobying the invention used in combination with a tubular reactor.

The drawing shows a reactor temperature control system for controlling the rate of coolant flow into a tubular reactor 10 having tubes 12 for the passage of an ethylene plus oxygen mixture. The reactor is particularly designed to oxidize ethylene into ethylene oxide with carbon dioxide and water as by-products.

An algorithm used to control the coolant flow into the reactor is now developed. The symbols used correspond to symbols used in the figure.

Let Q be the coolant flow rate and λ be its heat of vaporization. Assuming that there is no superheating of coolant, we have:

total heat removed by coolant=$Q\lambda$.

Let:

F_1=Reactor feed flow rate;
x_i=Concentration of component i in the reactor feed, where $i=1$ for ethylene, $i=2$ for carbon dioxide $i=3$ for ethane and $i=4$ for oxygen;

T_i=Feed temperature;
T_{Ref}=Reference temperature; and
C_{P_i}=Specific heat of feed.

Therefore, total enthalpy of feed=$F_1C_{P_i}(T_i-T_{Ref})$ (1)
where,

$$C_{P_i}=\sum_{k=1}^{4} C_{P_{ik}}\,x_i$$

where,
$C_{P_{ik}}$=specific heat of component $_k$.
Let:
F_2=Reactor effluent flow rate;
y_j=Concentration of component j in reactor effluent, where j=1 for ethylene oxide, j=2 for Co_2, j=3 for ethylene, j=4 for water; and
T_O=Reactor effluent temperature.
Then, by reaction stoichiometry:

$$y_2=y_4. \tag{2}$$

With the assumption that other impurities are small, we have:

$$y_1=1.0-y_2-y_3-y_4. \tag{3}$$

Ethylene oxide concentration may be either measured directly, or evaluated from equation (3).

Let:
ΔH_1=heat of reaction for ethylene oxidation into ethylene oxide; and
ΔH_2=heat of reaction for ethylene oxidation into carbon dioxide and water.
Then, heat generated in reactor
=heat of reaction (ethylene to ethylene oxide)+heat of reaction (ethylene to carbon dioxide)
$=F_2y_1\Delta H_1+F_2y_2\Delta H_2$.
Let
T_R=reaction temperature.
The heat consumed in elevating feed to reaction temperature=$F_1C_{P_i}$ (T_i-T_R)
Heat removed in cooling reaction products to reactor effluent temperature=$F_2C_{P_1}$ (T_R-T_O),
where

$$C_{P_1}=\sum_{m=1}^{4} y_mC_{P_m}$$

For total heat balance:
heat removed by coolant
=heat generated due to reaction+heat removed in cooling reaction products to reactor effluent temperature−heat used in heating feed to reaction temperature
or:

$$Q\lambda=F_2(y_1\Delta H_1+y_2\Delta H_2)+F_2C_{P_i}(T_R-T_O)-F_1C_{P_i}\ (T_R-T_i).$$

Thus:

$$Q=\frac{1}{\lambda}[F_2\{y_1\Delta H_1+y_2\Delta H_2+C_{P_i}\ (T_R-T_O)\}-F_1C_{P_i}\ (T_R=T_i)] \tag{4}$$

Equation (4) thus gives the desired coolant flow rate.

The sole figure of the drawing represents a reactor control scheme based on the above analysis. The implementation shown herein is via a conventional electronic instrumentation and control system. The invention, however, can easily be implemented via a control computer system. Startup and shutdown controls, although not shown herein, can be easily added to this control scheme.

In the illustrated system, ethylene is provided over line 14, with recycled ethylene being provided over line 16. Oxygen or air is provided over line 18. The flow of ethylene over line 14 is controlled by a valve 20 which receives a desired set point value at 22. The set point value can also be modified in controller 24 by a feedback loop generally designated 30 which includes a flow rate transmitter 26. Line 16 for recycling ethylene also includes flow transmitter 28. The flow of oxygen or air is controlled over a valve 32 in accordance with a ratio set at 34 of oxygen to ethylene. The combined feed flow rates of ethylene F_1 are added in summing element 40 and provided to a multiplication element 42. The effluent flow rate F_2 is determined in a flow rate transmitter 44 connected to the effluent line 46. Effluent line 46 contains the

desired product ethylene oxide plus carbon dioxide water, and unconverted ethylene. The concentration of ethylene oxide and carbon dioxide, y_1 and y_2, respectively, are obtained at a chromatography transmitter 50. The results of chromatography, that is, ethylene oxide and carbon dioxide concentration signals are used for determining the state of the catalyst. Ethylene oxide concentration signal is divided by carbon dioxide concentration signal in element 102 and displayed on a strip chart recorder 104. This element is useful to measure the state of the catalyst in the reactor, to determine whether the catalyst needs to be regenerated or replaced. The element can also be used in an emergency control for sounding an element and the like.

The carbon dioxide and ethylene oxide quantities are multiplied respectively by the heat of reaction for ethylene to carbon dioxide, ΔH_2, and the heat of reaction for ethylene to ethylene oxide, ΔH_1. These operations are accomplished in multiplication elements 54 and 56. The results of these two operations are added in adding element 58.

The maximum and minimum temperature within the reactor are determined using a temperature sensing means generally designated 60. Temperature sensing means 60 comprises a plurality of individual or banks of temperature sensors 62 which are distributed along the length of reactor 10. Elements 64 are utilizd to determine the maximum temperature among temperature sensors 62 and elements 66 are utilized to determine the minimum temperature among these sensors. Values for minimum and maximum temperature are applied by elements 68 and 70. The maximum and minimum temperatures are also processed in element 72 to yield a value T_R, the reaction temperature. A temperature sensor 74 is provided in the reactant input line 76 to sense the feed temperature T_I. This temperature is subtracted from the reactor temperature in subtracting element 78 which quantity is multiplied by the specific heat of the feed C_{PI} in multiplication element 80 and the result is divided by λ in division element 82. The resultant factor is multiplied in multiplication element 42 by the flow feed quantity F_1.

The reactor temperature T_I is also provided to subtraction element 84 where the effluent temperature T_O, as sensed by temperature transmitter 86, is subtracted therefrom. The result of the subtraction operation is multiplied by the specific heat quantity C_{PI} in multiplication element 88. The resultant is added in adding element 58 to the heater reaction components and the result of this operation is multiplied in multiplication element 90 by the flow rate F_2 as supplied over line 92. The result of this operation is divided by λ in division element 94. As mentioned above, the process time delay factor is considered in element 52. The subtraction element 96 is provided to subtract the input factors from the output factors to produce a coolant flow amount signal which it utilized in coolant flow controller 98 to control a coolant flow valve 100. Thus, the apparatus controls the temperature of an ethylene oxidation in a tubular reactor 10 by external cooling of the reactor tubes to which ethylene and oxygen/air are the feed streams and the reactor tubes contain catalyst.

Minimum and maximum reactor temperature is determined by the temperature sensors 62 and attached logic terminating in elements 64 and 66.

Either maximum or minimum temperature, whichever is beyond the associated operating limit as selected in elements 68 and 70, is selected in element 72 for the computation of desired coolant flow rate to the reactor.

In the illustrated system, the coolant flow rate is calculated from heat input/output balance. Actual ethylene conversion to ethylene oxide in the reactor is measured by measuring the ethylene oxide concentration in the reactor stream over chromatography transmitter 50. Actual ethylene conversion to carbon dioxide as a side reaction is also measured by the transmitter 50. The results of the chromatography signal computation is compensated for process time delay by element 52 prior to determining the coolant flow rate set point as applied to controller 98. The control system generates a signal which is based on carbon dioxide and ethylene oxide concentrations.

In the illustrated system, the reactor temperature is maintained between a narrow operating limit which is specified by the minimum and maximum operating temperature. In this way, ethylene conversion to ethylene oxide is maintained at an economical level as the specification of temperature limits is at least pseudo-optimal for a given catalyst, from the selectivity and conversion standpoint. Ethylene conversion to carbon dioxide is reduced as the reactor is operated within the temperature limit where catalyst selectivity toward carbon dioxide is minimal. Also, the reactor operation is within safety limits under all operating regimes, that is during start-up, shut-down and modulating control. The reactor operation is also within safe conditions for drastic variations in feed flow rate to the reactor.

The calculation of coolant flow rate set point in control 98 is based on ethylene conversion to carbon dioxide in addition, so that this provides for removing heat generated by the side reaction in addition to the heat generated by the desired reaction.

Additional indication signals are provided at chart recorder element 104 to display the state of the catalyst.

The control structure described above is a feed forward arrangement for the desired coolant flow rate prediction and feedback for coolant flow control.

Claims

1. A system for controlling the temperature of a reactor (10) for containing a reaction from at least one reactant to at least one product, the reactor having a feed line (14) for the reactant and an effluent line (46) for the product, the system being characterised by:

a feed flow transmitter (26) connected to the feed line (14) for measuring the flow of reactant to the reactor (10);

an effluent flow transmitter (44) connected to the effluent line (46) for measuring the flow of product from the reactor (10);

a feed temperature sensor (74) connected to the feed line for sensing the reactant temperature; an effluent temperature sensor (86) connected to the effluent line (46) for measuring the product temperature;

reactor temperature sensing means (60) connected to the reactor (10) for measuring a temperature of the reactor;

concentration sensing means (50) connected to the effluent line (46) for measuring the concentration of the at least one product in the effluent line;

a coolant flow line to the reactor (10) for supplying coolant to the reactor at a coolant flow rate;

coolant flow rate control means (100) in the coolant line; and

circuit means that is

(i) connected to the feed and effluent flow transmitters (26, 44), to the feed and effluent temperature sensors (74, 86) and to the reactor temperature and concentration sensing means (60, 50) for generating a coolant flow signal,

(ii) connected to the coolant flow control means (100) for controlling the flow of coolant to the reactor (10) according to the coolant flow signal,

(iii) arranged to receive quantities proportional to the heat of reaction for at least one reaction in the reactor (10), specific heats of the reactant and product, and the heat of vaporization of the coolant, and

(iv) operable to subtract a quantity proportional to an amount of heat consumed in supplying reactant to the reactor (10) from a quantity proportional to an amount of heat generated and lost in the reactor and effluent line and to divide the resulting quantity by the specific heat of the coolant to generate the coolant flow signal.

2. A system according to Claim 1, wherein the circuit means is operable to generate the coolant flow signal (Q) using the formula

$$Q=\frac{1}{\lambda}[F_2\{y_1\Delta H_1+y_2\Delta H_2+C_{Pl}(T_R-T_O)\}-F_1C_{PI}(T_R-T_I)]$$

where:

Q=coolant flow rate signal
λ=coolant heat of vaporization
F_2=effluent flow rate
y_1=a first product concentration
ΔH_1=heat of reaction of reactant to first product
y_2=a second product concentration
ΔH_2=heat of reaction of reactant to second product
C_{Pl}=specific heat of effluent
T_R=reactor temperature
T_O=effluent temperature
F_1=feed flow rate
C_{PI}=specific heat of feed
T_I=feed temperature.

3. A system according to Claim 1 or Claim 2, wherein the reactor temperature sensing means (60) comprises a plurality of temperature sensors (62) distributed along the length of the reactor (10) and a minimizing/maximizing circuit (64, 66, 68, 70) connected to the temperature sensors (62) for obtaining a minimum and a maximum temperature among the temperature sensors of the reactor.

4. A method of controlling the temperature of a reactor (10) for containing an exothermic reaction of at least one reactant to at least one product, by controlling a flow of coolant to the reactor, the method being characterised by:

measuring a feed and an effluent flow rate to and from the reactor of reactant and product;

measuring a feed and effluent temperature;

measuring a reactor temperature;

measuring a concentration of the at least one product in the effluent; and

calculating a coolant flow rate using the formula

$$Q=\frac{1}{\lambda}[F_2\{y_1\Delta H_1+y_2\Delta H_2+C_{Pl}(T_R-T_O)\}-F_1C_{PI}(T_R-T_I)$$

where:

Q=coolant flow rate signal
λ=coolant heat of vaporization
F_2=effluent flow rate
y_1=a first product concentration
ΔH_1=heat of reaction of reactant to first product
y_2=a second product concentration
ΔH_2=heat of reaction of reactant to second product
C_{PI}=specific heat of effluent
T_R=reactor temperature
T_O=effluent temperature
F_1=feed flow rate
C_{PI}=specific heat of feed
T_I=feed temperature.

5. A method according to Claim 4, wherein ethylene plus oxygen is supplied to the reactor as reactant and ethylene oxide plus carbon dioxide and water are generated as products, y_1 being the concentration of ethylene oxide, y_2 being the concentration of carbon dioxide, ΔH_1 being the heat of reaction of ethylene plus oxygen to ethylene oxide, and ΔH_2 being the heat of reaction of ethylene plus oxygen to carbon dioxide.

Patentansprüche

1. System zur Steuerung der Temperatur eines Reaktors (10) der eine Umsetzung wenigstens eines Reaktionspartners zu wenigstens einem Produkt enthalten soll, wobei der Reaktor eine Beschickungsleitung (14) für den Reaktionspartner und eine Auslaufleitung (46) für das Produkt hat, gekennzeichnet durch

einen Beschickungsstromsender (26), der mit der Beschikkungsleitung (14) für eine Messung des Reaktionsparnerstromes zu dem Reaktor (10) verbunden ist;

einen Auslaufstromsender (44), der mit der Auslaufleitung (46) zur Messung des Produktstromes aus dem Reaktor (10) verbunden ist;

einen Beschickungstemperaturfühler (74), der mit der Beschickungsleitung zum Abfühlen der Reaktionspartnertemperatur verbunden ist;

einen Auslauftemperaturfühler (86), der mit der Auslaufleitung (46) zur Messung der Produkttemperatur verbunden ist;

eine Reaktortemperaturabfühleinrichtung (60), die mit dem Reaktor (10) zur Messung einer Temperatur des Reaktors verbunden ist;

eine Konzentrationabfühleinrichtung (50), die mit der Auslaufleitung (46) zur Messung der Konzentration wenigstens eines Produktes in der Auslaufleitung verbunden ist;

eine Kühlmittelstromleitung zu dem Reaktor (10), um Kühlmittel dem Reaktor mit einer Kühlmittelströmungsgeschwindigkeit zuzuführen;

eine Kühlmittelströmungsgeschwindigkeitsteuereinrichtung (100) in der Kühlmittelleitung und eine Schaltung, die

(i) mit den Beschickungs- und Auslaufstromsendern (26, 44), den Beschickungs- und Auslauftemperaturfühlern (74, 86) und den Reaktortemperatur- und Konzentrationsabfühleinrichtungen (60, 50) verbunden ist, um ein Kühlmittelstromsignal zu erzeugen,

(ii) mit der Kühlmittelstromsteuereinrichtung (100) verbunden ist, um den Kühlmittelstrom zu dem Reaktor (10) gemäß dem Kühlmittelstromsignal zu steuern,

(iii) so angeordnet ist, daß sie Mengen proportional der Reaktionswärme für wenigstens eine Umsetzung in dem Reaktor (10), der spezifischen Wärme des Reaktionspartners und des Produktes und der Verdampfungswärme des Kühlmittels aufnimmt und

(iv) so arbeitet, daß sie eine Menge proportional zu einer Wärmemenge, die bei der Zuführung von Reaktionspartner zu dem Reaktor (10) verbraucht wird, von einer Menge proportional zu einer Wärmemenge, die in dem Raktor der Auslaufleitung erzeugt wird und verlorengeht, abzieht aus die resultierende Menge durch die spezifische Wärme des Kühlmittels teilt, um so das Kühlmittelstromsignal zu erzeugen.

2. System nach Anspruch 1, bei dem die Schaltung so arbeitet, daß sie das Kühlmittelstromsignal (Q) unter Verwendung der folgenden Formel erzeugt:

$$Q=\frac{1}{\lambda}[F_2(y_1\Delta H_1+y_2\Delta H_2+C_{PI}(T_R-T_O))-F_1C_{PI}(T_R-T_I)]$$

worin:

Q=Kühlmittelströmungsgeschwindigkeitssignal
λ=Kühlmittelverdampfungswärme
F_2=Auslaufströmungsgeschwindigkeit

y_1=eine erste Produktkonzentration
ΔH_1=Reaktionswärme von Reaktionspartner zu einem ersten Produkt
y_2=eine zweite Produktkonzentration
ΔH_2=Reaktionswärme von Reaktionspartner zu einem zweiten Produkt
C_{Pl}=spezifische Wärme des Auslaufs
T_R=Reaktortemperatur
T_O=Auslauftemperatur
F_1=Beschickungsstromgeschwindigkeit
C_{PI}=spezifische Wärme der Beschickung
T_I=Beschickungstemperatur.

3. System nach Anspruch 1 oder Anspruch 2, bei dem die Reaktortemperaturabfühleinrichtung (60) mehrere Temperaturfühler (62), die enthlang der Länge des Reaktors (10) verteilt sind, und eine Minimier/Maximierschaltung (64, 66, 68, 70), die mit dem Temperaturfühlern (62) verbunden ist, aufweist, um bei den Temperaturfühlern des Reaktors eine Minimum- und eine Maximumtemperatur zu bekommen.

4. Verfahren zur Steuerung der Temperatur eines Reaktors (10), die eine exotherme Reaktion wenigstens eines Reaktionspartners zu wenigstens einem Produkt enthalten soll, durch Steuerung eines Kühlmittelstromes zu dem Reaktor, dadurch gekennzeichnet, daß man

eine Beschickungs- und eine Auslaufstromgeschwindigkeit von Reaktionspartner und Produkt zu und von dem Reaktor mißt,
eine Beschickungs- und Auslauftemperatur mißt,
eine Reaktortemperatur mißt,
eine Konzentration wenigstens eines Produktes in dem Auslauf mißt und
eine Kühlmittelstromgeschwindigkeit unter Verwendung der folgenden Formel berechnet:

$$Q=\frac{1}{\lambda}[F_2\{y_1\Delta H_1+y_2\Delta H_2+C_{Pl}(T_R-T_O)\}-F_1C_{PI}(T_R-T_I)]$$

worin:
Q=Kühlmittelströmungsgeschwindigkeitssignal
λ=Kühlmittelverdampfungswärme
F_2=Auslaufströmungsgeschwindigkeit
y_1=eine erste Produktkonzentration
ΔH_1=Reaktionswärme von Reaktionspartner zu einem ersten Produkt
y_2=eine zweite Produktkonzentration
ΔH_2=Reaktionswärme von Reaktionspartner zu einem zweiten Produkt
C_{Pl}=spezifische Wärme des Auslaufs
T_R=Reaktortemperatur
T_O=Auslauftemperatur
F_1=Beschickungsstromgeschwindigkeit
C_{PI}=spezifische Wärme der Beschickung
T_I=Beschickungstemperatur.

5. Verfahren nach Anspruch 4, bei dem Ethylen plus Sauerstoff einem Reaktor als Reaktionspartner zugeführt werden und Ethylenoxid plus Kohlendioxid und Wasser als Produkte erzeugt werden, wobei y_1 die Ethylenoxidkonzentration ist, y_2 die Kohlendioxidkonzentration ist, ΔH_1 die Reaktionswärme von Ethylen plus Sauerstoff zu Ethylenoxid ist und ΔH_2 die Reaktionswärme von Ethylen plus Sauerstoff zu Kohlendioxid ist.

Revendications

1. Système pour régler la température d'un réacteur (10) afin de contenir une réaction d'au moins un réactant en au moins un produit, le réacteur présentant une conduite d'amenee (14) pour réactant et une conduite d'effluent (46) pour le produit, le système étant caractérisé par:

un transmetteur de débit de produit arrivant (26) relié à la conduite d'amenée (14) pour mesurer le débit d'arrivée de réactant au réacteur (10);
un transmetteur de débit d'effluent (44) relié à la conduite d'effluent (46) pour mesurer le débit de sortie de produit à partir du réacteur (10);
un capteur de température de produit arrivant (74) relié à la conduite d'amenée pour déceler la température du réactant;
un capteur de température d'effluent (86) relié à la conduite d'effluent (46) pour mesurer la température du produit;
un moyen détecteur de température de réacteur (60) relié au réacteur (10) pour mesurer une température du réacteur;
un moyen détecteur de concentration (50) relié à la conduite d'effluent (46) pour mesurer la concentration du ou des produits présents dans la conduite d'effluent;

une conduite d'arrivée de caloporteur au réacteur (10) pour l'amenée de caloporteur au réacteur à un débit de caloporteur;

un moyen de réglage du débit du caloporteur (100) présent dans la conduite de caloporteur; et un montage qui est

(i) relié aux transmetteurs de débit de produit arrivant et d'effluent (26, 44) aux capteurs de température de produit arrivant et d'effluent (74, 86) et aux moyens détecteurs de température de réacteur et de concentration (60, 50) pour générer un signal de débit de caloporteur,

(ii) relié au moyen de réglage de débit de caloporteur (100) pour régler le débit d'arrivée de caloporteur au réacteur (10) en fonction du signal de débit de caloporteur,

(iii) agencé pour recevoir des quantités proportionnelles à la chaleur de réaction pour au moins une réaction intervenant dans le réacteur (10), aux chaleurs spécifiques du réactant et du produit et à la chaleur de vaporisation du caloporteur, et

(iv) agissant pour soustraire une quantité proportionnelle à un total de chaleur consommée dans l'envoi de réactant au réacteur (10) d'une quantité proportionelle à un total de chaleur générée et perdue dans le réacteur et dans la conduite d'effluent et pour diviser la quantité résultante par la chaleur spécifique du caloporteur afin de générer le signal de débit de caloporteur.

2. Système selon la revendication 1, dans lequel le montage assure la génération du signal de débit de caloporteur (Q) en utilisant la formule

$$Q=\frac{1}{\lambda}[F_2\{y_1\Delta H_1+y_2\Delta H_2+C_{PI}(T_R-T_O)\}-F_1C_{PI}(T_R-T_I)]$$

où:

Q=signal de débit de caloporteur
λ=chaleur de vaporisation du caloporteur
F_2=débit d'effluent
y_1=concentration d'un premier produit
ΔH_1=chaleur de réaction de transformation du réactant en premier produit
y_2=concentration d'un second produit
ΔH_2=chaleur de réaction de transformation du réactant en second produit
C_{PI}=chaleur spécifique de l'effluent
T_R=température du réacteur
T_O=température de l'effluent
F_1=débit de produit arrivant
C_{PI}=chaleur spécifique du produit arrivant
T_I=température du produit arrivant.

3. Système selon la revendication 1 ou la revendication 2, dans lequel le moyen de détection de température de réacteur (60) comprend une pluralité de capteurs de température (62) répartis sur la longueur du réacteur (10) et un circuit de minimisation/maximisation (64, 66, 68, 70) relié aux capteurs de température (62) pour obtenir une température minimale et une température maximale parmi les capteurs du réacteur.

4. Procédé de réglage de la température d'un réacteur (10) afin de contenir une réaction exothermique d'au moins un réactant en au moins un produit, par réglage du débit d'arrivée du caloporteur au réacteur, le procédé étant caractérisé en ce que:

on mesure le débit d'arrivée au réacteur et de sortie du réacteur de réactant et de produit;
on mesure la température de produit arrivant et d'effluent;
on mesure une température du réacteur;
on mesure la concentration du ou des produits présents dans l'effluent; et
on calcule le débit de caloporteur à l'aide de la formule

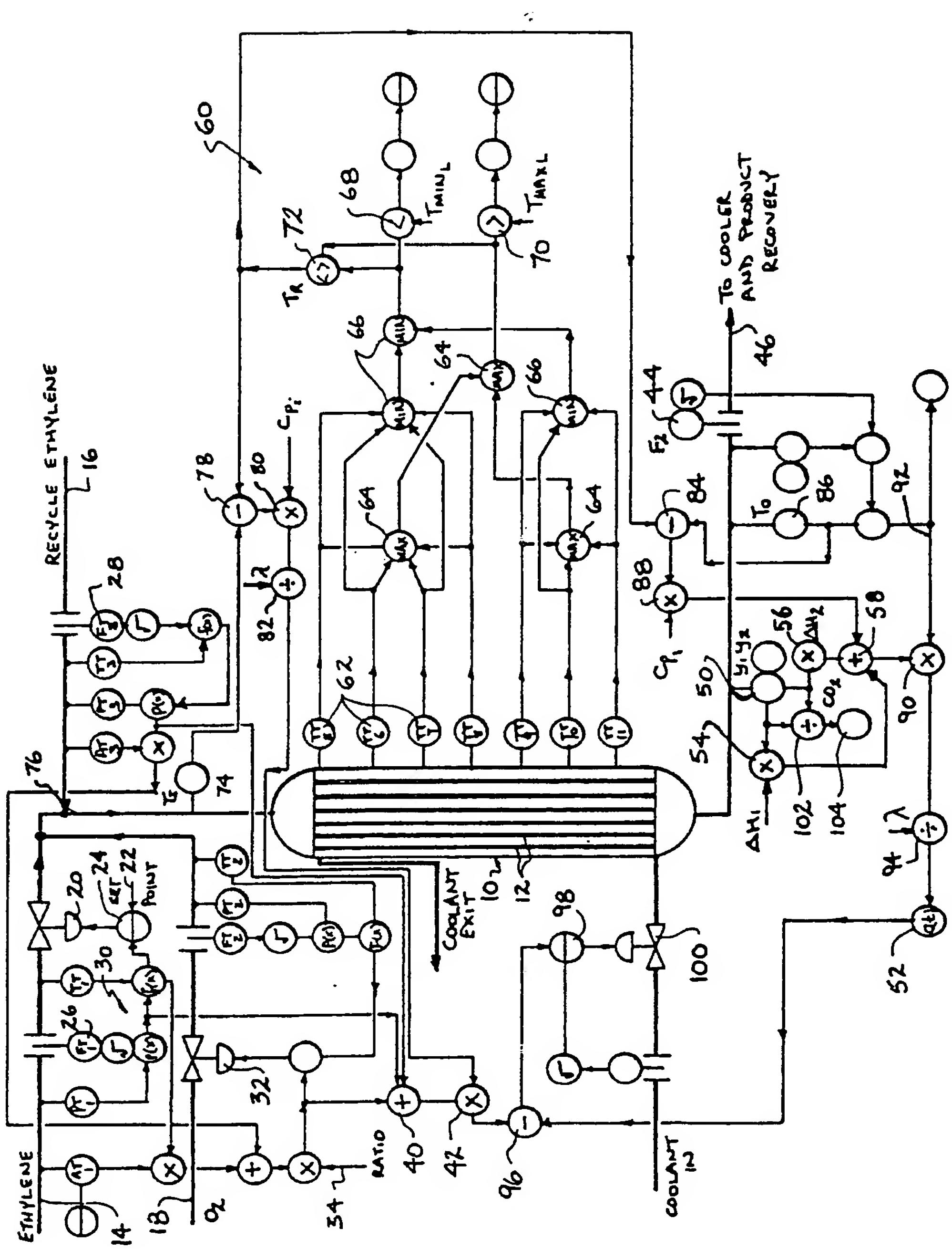
$$Q=\frac{1}{\lambda}[F_2\{y_1\Delta H_1+y_2\Delta H_2+C_{PI}(T_R-T_O)\}-F_1C_{PI}(T_R-T_I)]$$

où:

Q=signal de débit de caloporteur
λ=chaleur de vaporisation du caloporteur
F_2=débit d'effluent
y_1=concentration d'un premier produit
ΔH_1=chaleur de réaction de transformation du réactant en premier produit
y_2=concentration d'un second produit
ΔH_2=chaleur de réaction de transformation du réactant en second produit
C_{PI}=chaleur spécifique de l'effluent
T_R=température du réacteur
T_O=température de l'effluent

F_1=débit de produit arrivant
C_{PI}=chaleur spécifique du produit arrivant
T_I=température du produit arrivant.

5. Procédé selon la revendication 4, dans lequel de l'éthylène plus de l'oxygène arrive au réacteur en tant que réactant et de l'oxyde d'éthylène plus du dioxyde de carbone et eau sont générés en tant que produits, y_1 étant la concentration en oxyde d'éthylène, y_2 étant la concentration en dioxyde de carbone, ΔH_1 étant la chaleur de réaction de l'éthylène plus de l'oxygène en oxyde d'éthylène, et ΔH_2 étant la chaleur de réaction de l'éthylène plus de l'oxygène en dioxyde de carbone.


ETHYLENE
RECYCLE ETHYLENE
SET POINT
RATIO
COOLANT EXIT
COOLANT IN
TO COOLER AND PRODUCT RECOVERY